NOWCAST for the Next Generation Navy

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Award Number: N0001405WX20413
http://cat.metoc.nrlmry.navy.mil/nowcast

LONG-TERM GOALS

This project is one coordinated component of a larger effort to address specific operational decisions that are affected by meteorology and oceanography (METOC) processes. Our goal is to develop technology for a high-resolution weather data fusion (NOWCAST) system capable of blending and assimilating an ensemble of highly perishable, on-scene environmental data into an integrated picture of the battlespace environment. NOWCAST will provide the Navy or Joint METOC operator with a real-time, automated, web-based system to help monitor and characterize the impact of rapidly changing, operationally significant weather situations. NOWCAST offers a situational awareness framework that will enable warfighters and decision-makers to consider the impacts of the environment, which in turn will improve coordination and efficiency, both within the battlegroup and in the target area. Initially, the situational awareness of weather hazard information is primarily intended to support naval aviation in time critical/sensitive strike missions, but in the future, the capability may be extended to improve safety, navigation, ship self defense, special warfare, weaponeering, and other operational areas impacted by the environment. The NOWCAST system, data, and products will be owned, operated, maintained, and quality assured by the METOC office.

OBJECTIVES

The specific objectives of this project within the larger effort are to design and develop the prototype web-enabled NOWCAST system as an integration of data fusion and data assimilation technologies; to invent weather impact products utilizing a wide variety of data sources, both conventional and "through-the-sensor", including development of innovative data acquisition and processing software; and to obtain end-user buy-in through a series of high-level briefings and an Integrated Product Team (IPT) process. The IPT process is designed to ensure that the products developed for NOWCAST meet the warfighter's decision-making needs, that the NOWCAST architecture fits within the overall Navy web-enabled, net-centric, FORCENet vision, and that the METOC office can be responsible for NOWCAST operations and maintenance.

APPROACH

To meet the challenge of utilizing METOC data available at asynoptic times collected by forward-deployed units, the Naval Research Laboratory (NRL) has developed the Coupled Ocean/Atmosphere

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2005		**00-00-2005 to 00-00-2005**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
NOWCAST for the Next Generation Navy	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory,Marine Meteorology Division,7 Grace Hopper Avenue,Monterey,CA,93943**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
code 1 only

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**9**	

Mesoscale Prediction System – On-Scene (COAMPS-OS®) data assimilation system. COAMPS-OS has been significantly enhanced to support a suite of integrated NOWCAST software components that include a high-resolution 3-D cloud analysis, a radar wind analysis, interfaces to the COAMPS® gridded data fields and conventional observation data, interfaces to the METOC FMQ-17 (shore) and SMQ-11 (shipboard) satellite data processing systems for satellite data, and interfaces to a NOAA data feed for NEXRAD level II and level III radar data as a precursor to DoD radar data. When available, NOWCAST can also use data from non-traditional sources focused around the battlegroup and target areas. For example, the SPS-48 air search radars and other tactical radars of opportunity can provide weather radar data around the battlegroup and unmanned aerial systems (UAS) may provide a rich set of target area weather observations. To use these unconventional data in real-time requires us to adapt and develop advanced data assimilation techniques as well as machine intelligent feature detection and artificial intelligence (AI) data fusion technology to create an automatic environmental data fusion/assimilation engine. In addition, NOWCAST uses established web-based product dissemination and display technology to overcome fleet firewall policy limitations and minimize end-user training issues. The NOWCAST software application is configurable to allow the warfighter users to tailor their results to their specific operational requirements.

Another principal effort in this project is devoted to the development of high-level support and end-user buy-in to NOWCAST. To facilitate this interaction, a series of high-level briefings and meetings to senior Navy decision makers in the aviation, surface warfare, and METOC communities have been on going to expose the concept of NOWCAST and to generate support. In FY04, we received ONR and Oceanographer of the Navy (N7C) support to partner with the Naval Strike and Air Warfare Center (NSAWC) and the METOC Detachment at Fallon, NV in a Rapid Transition Project (RTP) to create a shore test and development site for NOWCAST to demonstrate enhanced weather support to strike warfare (N0001405WX20414). We view the success of this project to be directly related to acceptance by the end-users. Without a feedback mechanism between the S&T process and the end-users, it is possible to be scientifically and technically correct, but produce results that are not useful. We have had four IPT meetings for NOWCAST, focused on interaction between the warfighting, METOC, and S&T communities.

Another key element of our approach is to leverage other projects at NRL and at other agencies. An NRL Base project recently completed after adapting the cloud analysis components of the University of Oklahoma's ARPS (Advanced Regional Prediction System) Data Assimilation System (ADAS) to NOWCAST. The ONR Shipboard Radar Data Assimilation System project (N0001405WR20187) has supported NOWCAST with development of both automatic product verification technology and development of the 3.5DVAR technique to assimilate model and radar data to create accurate high-resolution analyses of local wind and temperature fields. NRL has also completed a major Ceiling and Visibility (C&V) technology development funded by the FAA, NASA, and Navy (N7C), to provide improved C&V NOWCAST products.

WORK COMPLETED

A prototype web-enabled NOWCAST system was designed, developed, and demonstrated at NRL Monterey in FY00. The prototype system leverages technology developed for the NRL Atmospheric Variational Data Assimilation System (NAVDAS) for conventional data quality control and data

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assimilation. The system accesses data through the operational Tactical Environmental Database System (TEDS).

The effort for FY01 was focused on developing the technology to acquire and process new data types. In cooperation with the NRL Base and ONR projects described above, a real-time data interface and processing capability for level III NEXRAD radar data was developed and transitioned to Fleet Numerical Meteorology and Oceanography Center (FNMOC). A ceiling height and visibility algorithm developed by the National Center for Atmospheric Research (NCAR) was adapted and implemented in NOWCAST to produce C&V products every 15 minutes. The ADAS cloud analysis system was adapted and implemented in NOWCAST and used to compute volume cloud elements every hour.

In FY02, the NOWCAST user interface was completely redesigned and recoded to overcome problems with the original prototype that limited user functionality and caused unreliable performance. An analysis of SPY-1 Tactical Environmental Processor (TEP) radar data collected during a Joint Task Force Exercise (JTFX) was also completed; however, the data contained a number of artifacts and clutter that had to be manually removed. The need to develop automated processing and quality control algorithms for mobile radar data was recognized and addressed in an NRL Base new start.

In FY03, the NOWCAST team developed the capability to process, fuse and display full-volume, full-resolution level II radar data from individual operational NOAA Next Generation Weather Radar (NEXRAD) radar stations, similar to how we envision accessing, processing, and displaying data from DoD radars in the future. During this effort NRL was established as a contributing member of the Collaborative Radar Acquisition Field Test (CRAFT) project (now Integrated Radar Data Services (IRaDS); see https://www.radarservices.org for details). New products were also integrated into NOWCAST including three-dimensional winds to support aircraft operations and chemical/biological dispersion models, lightning data, and NEXRAD level III Velocity Azimuth Display (VAD) wind profiles. NOWCAST software was adapted to the personal computer running the Linux operating system, significantly reducing the expected transition costs for the system in the future.

The efficiency, reliability, accessibility, and user support of the NOWCAST server, client and products were substantially improved during FY04, for example, a more efficient radar level III processing system was developed, tested, and implemented and the NOWCAST client was converted to a Java Web Start application to allow the client to run outside the limited browser area. Also, interfaces for Geographic Information Systems (GIS) using Geographic Markup Language (GML) following the Open GIS standards were created for the NOWCAST server to allow clients that adhere to these standards (e.g., ESRI ArcView) to access NOWCAST products. Enhancements were also made to the quality control and format of the VAD wind profile, to the severe weather product overlaying of satellite imagery and level III composite reflectivity images, and a new day-night terminator was created to help diagnose surface heating and cooling effects. In addition, software was developed to create and display NEXRAD level III-like products from level II Supplemental Weather Radar (SWR) data acquired from Navy shore sites (e.g., Point Loma, CA, and Fallon, NV).

Substantial progress was also made in research and development applications for NOWCAST in FY04. A three-dimensional radar mosaic system was developed that integrates volumetric scans of reflectivity data from a selected region of individual radars onto a Cartesian grid. A radar data de-aliaser and VAD wind algorithm were also created for level II data from DoD radars such as the SWR and SPS-48. Research was conducted on the state-of-the-art in radar radial velocity and it was concluded that

the Gradient VAD (GVAD) method of Gao et al. (2004) would be a suitable choice for NOWCAST. A stand-alone algorithm was developed whereby the GVAD method was used to create an environmental wind table necessary for de-aliasing, with the option of using COAMPS wind profiles to fill in any missing GVAD estimates in the event of insufficient radar data.

In FY05, several significant additions and further enhancements were made to the NOWCAST system. In coordination with the Radar Data Assimilation project, the 3.5DVAR technique was implemented with COAMPS-OS and interfaced to NOWCAST. This effort allows us to combine the data assimilation technology with the data fusion technology into a single system for nearly continuous high resolution environmental assessment and forecasting. In addition, the development of an Open GIS Consortium (OGC) compliant web mapping server that was started in FY04 was completed. Figure 1 shows the NOWCAST user interface that implements the new services. Using a freely-available OGC compliant software package, a fully-GIS compliant client interface (Figure 2) was developed to demonstrate the NOWCAST GIS server capabilities and to provide an example of how to couple NOWCAST and COAMPS products into a third-party software suite as the paradigm we envision the Command and Control systems will adopt in the future. In coordination with the RTP project, National Center for Atmospheric Research (NCAR) Thunderstorm Identification, Tracking, Analysis and Nowcasting (TITAN) algorithm was implemented at NRL Monterey and interfaced to our real-time radar data stream. TITAN is currently being configured to perform optimally on our data and the output is in the process of being integrated and evaluated as a NOWCAST product. TITAN provides automated estimates of thunderstorm location and movement as well as 30, 60, and 120 min forecasts of thunderstorm location, updated every 10 min. Substantial progress was also made on developing the METQC automated quality control and verification capability for NOWCAST, leveraging the investment in NAVDAS. Although still not yet fully integrated, the prototype METQC system is cycling on real data and providing useful information for model developers. We anticipate that through the IPT process the end user displays will be refined. A new NOWCAST product displaying user-configured time series products was also completed. A similar product for cross sections following a flight path is still in development.

RESULTS

The enhanced NOWCAST system developed this year now fuses a wider variety of data types, supports more mission impact areas, and handles a larger number of concurrent users than the previous version, all within the context of a coupled high-resolution data assimilation/data fusion/forecasting system interfaced to a suite of standardized OGC compliant GIS web services. Based on the number of presentations describing a similar approach from nowcasting groups from around the world at the recent World Weather Research Programme's Symposium on Nowcasting and Very Short Range Forecasting (WSN05), our approach appears to be validated. Our capability has the added feature of global relocatability lacking in virtually every other system because they have been designed for a specific data rich geographic area.

While testing the GVAD-based radar radial velocity de-aliasing algorithm, we learned that the statistical uncertainty in the GVAD wind profiles was often too large so that the winds would be filtered out if used directly with the existing VAD quality controller developed for NOWCAST this year. However, we learned that the GVAD wind profiles were of sufficient precision and accuracy to still serve as the reliable source of input for the environmental wind table described above. Thus, it was decided to use GVAD only for de-aliasing and the original VAD method on the de-aliased radial velocity for the VAD product (QC Radar Winds) on NOWCAST. By way of demonstration of the

new capabilities in NOWCAST, Figure 3 shows various level III display products generated from NEXRAD level II data of Hurricane Charley (2004) using the software that will be used to do the same with level II DoD radar data when it becomes available. Note the dramatic improvement in the radial velocity display in comparing Figures 3a (raw radial velocity) and 3b (de-aliased radial velocity). Also shown are products derived from the full radar volume scan: the VAD wind profile derived from the de-aliased radial velocity data (Figure 3d) and the composite reflectivity (Figure 3c) generated from the reflectivity data.

Figure 1. NOWCAST Geographic Information System (GIS) interface showing radar reflectivity data overlaid on visible satellite imagery for Florida.

Our interactions with warfighters have reinforced their priorities for data fusion and decision-enabling products in the target areas, enroute, and in the carrier launch and recovery areas. We find a continuing need for NOWCAST to supplement existing METOC forecast assets with an automated capability to continuously assimilate and fuse observations from all sources including radar and UAV "through-the-sensor" observations. NOWCAST also needs to continue to include intuitive quality control features so that the system is easy to use, operate, maintain, and monitor, and the system needs to be designed to minimize training requirements as greater stress is applied to METOC manning at sea. NOWCAST needs to interface to the Naval Fires Network (NFN) and other Command and Control architectures, such as FORCENet, to help realize the benefits of net-centric warfare and four-

dimensional battlespace awareness. The capability to operationally display DoD SWR radar data from Fallon, NV radar data and derived-products on NOWCAST is now a reality. This capability will also be tested when sample SPS-48 radar data from SPAWAR become available.

IMPACT/APPLICATIONS

NOWCAST is the focus of a telescoping strategy to provide environmental products tailored to the decision-making needs of the warfighter, from global scales down to tactical scales in both time and space. NOWCAST also represents a paradigm shift from periodic products that are briefed and interpreted by METOC personnel to nearly continuous products that are easily accessible over the web, automatically updated, and tailored for interpretation directly by the warfighter. NOWCAST enhances the role of METOC support by supplementing the existing forecast capability with continuous, automated, short-term (less than 2 hours) decision-enabling products, thus freeing the forecaster to concentrate on the longer-range projections for planning and evaluation purposes.

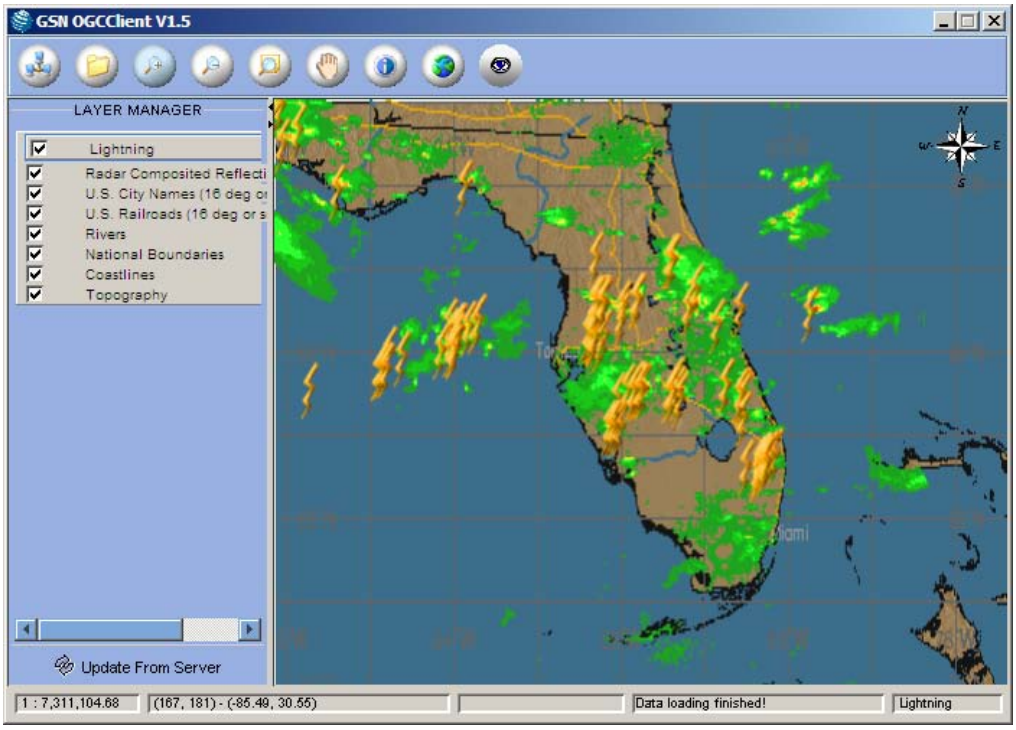

Figure 2. An example of an open source Open Geographic Information System (GIS) Consortium (OGC) compliant client interface displaying radar reflectivity data and lightning data product overlays for Florida provided by the NOWCAST OGC compliant web mapping service.

TRANSITIONS

An early transition in FY01 was a stand-alone radar capability implemented at FNMOC. In FY04, the ADAS cloud analysis system was transitioned to COAMPS-OS Version 1.3 for providing real-time three-dimensional clouds, ceiling and visibility for NOWCAST. Also in FY04, the RTP project was established at the Naval Pacific METOC Detachment, Fallon, NV. In FY05, the 3.5DVAR radar wind analysis capability was transitioned to COAMPS-OS Version 1.4.

RELATED PROJECTS

In addition to the ONR Shipboard Data Assimilation System development project (N0001405WR20187) and the RTP shore test and development site at Fallon, NV (ONR: N001405WX20414 and N7C: PE 0603207N X2342) projects described above, the NRL Base Optimum Use of DoD Radar in Battlespace Environmental Prediction project, and a similar SPAWAR Systems Center project using the SPS-48 radar are important to NOWCAST for weather radar technology at sea. The National Weather Radar Testbed (NWRT) at the National Severe Storms Laboratory (NSSL) will be a critical source of radar data processing and quality control technology. Automated chemical and biological dispersion technology has been adapted to NOWCAST under Defense Threat Reduction Agency (DTRA) sponsorship.

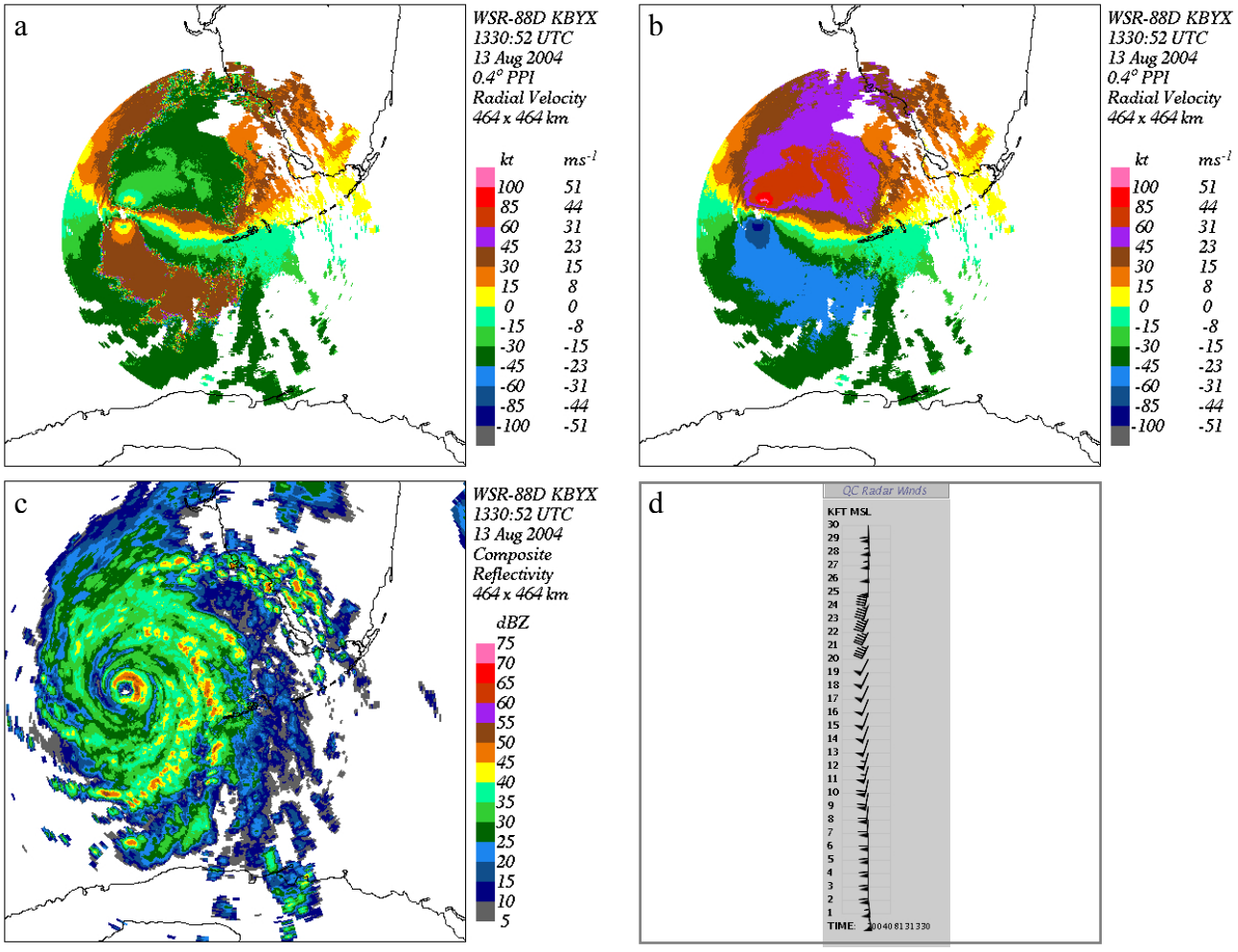

Figure 3. NOWCAST radar data products for Hurricane Charley taken from the Key West (KBYX), Florida, NEXRAD radar on 13 Aug 2004 1330:52 UTC. a) Raw radial velocity from the lowest elevation angle scan. b) De-aliased radial velocity from the lowest elevation angle scan. c) Composite reflectivity. d) VAD wind profile for KBY

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